

AD-A116 413

NAVAL POSTGRADUATE SCHOOL MONTEREY CA

F/G 17/5

A TARGET ACQUISITION MODULE FOR THE STAR COMBINED ARMS COMBAT S--ETC(U)

JAN 82 J K HARTMAN

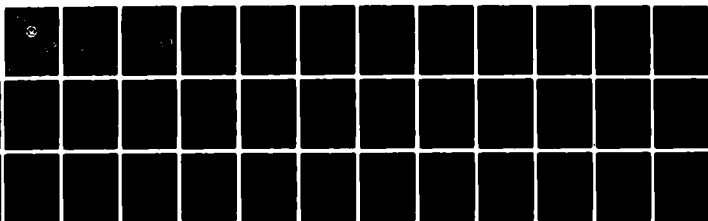
MIPR-CD-2-82

UNCLASSIFIED

NPS55-82-001

NL

1 of 1
AD-A
116-413



END

DATE

FILED

09:82

DTIC

Report Number -- NPS55-82-001

NAVAL POSTGRADUATE SCHOOL

Monterey, California



AD A118413

A TARGET ACQUISITION MODULE
FOR THE
STAR COMBINED ARMS COMBAT SIMULATION
VOLUME I
USERS MANUAL

James K. Hartman

January 1982

DTIC
AUG 20 1982
H

Approved for public release; distribution unlimited

Prepared for:
US Army Training and Doctrine Command, Fort Monroe VA 23651

DTIC FILE COPY

82 08 20 047


NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

Rear Admiral J. J. Ekelund
Superintendent

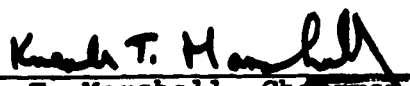
David A. Schrady
Acting Provost

This work was supported by the U.S. Army Training and
Doctrine Command, Fort Monroe, VA 23651.

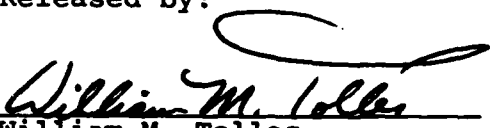
The report was prepared by:


James K. Hartman, Associate Professor
Department of Operations Research

Reviewed by:


K. T. Marshall, Chairman
Department of Operations Research

Released by:


William M. Tolles
Dean of Research

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS55-82-001	2. GOVT ACCESSION NO. AD-A118 413	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Target Acquisition Module for the STAR Combined Arms Combat Simulation, Volume I, Users Manual		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) James K. Hartman		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS MIPR# CD-2-82
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Training and Doctrine Command Fort Monroe, Virginia 23651		12. REPORT DATE January 1982
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 35
		15. SECURITY CLASS. (of this report) U
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Target Acquisition, Detection, Search, STAR, Combat Models, NVL, Simulation, Electrooptical		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report provides user documentation for the Target Acquisition module of the STAR combined arms combat simulation model. The Target Acquisition module allows STAR to simulate the detailed tactical employment of existing and proposed electro-optical imaging sensors in degraded visibility scenarios involving night, weather, and battlefield smoke. Sensor device models developed by NVL are incorporated to model the basic target detection phenomenon. A variety of search tactics model the ways in which these sensor devices are used.		

DTIC
AUG 20 1982
H

DD FORM 1473
1 JAN 73

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

	PAGE
I. EXECUTIVE SUMMARY	
A. Major Features of the Target Acquisition Module.....	1
B. Structure of the Target Acquisition Module.....	1
II. OVERVIEW OF THE STAR TARGET ACQUISITION MODULE	
A. Introduction.....	3
B. Event Flow in STAR.....	4
C. Basic Structure of the Target Acquisition Module.....	5
D. The NVL Detection Model.....	7
III. INPUTS TO THE NVL MODEL - DEFINING SENSOR DEVICES	
A. The NVL Methodology.....	8
B. Extensions.....	17
IV. INPUTS TO SEARCH TACTICS - USING SENSOR DEVICES	
A. The Concept of a Search Tactic.....	19
B. Associating a Search Tactic and Sensors with an Observer.....	21
C. Parameters for a Single-Sensor Search Tactic.....	23
D. Application of the STK2 Search Tactic.....	27
V. SUMMARY OF TARGET ACQUISITION INPUT PARAMETERS	
A. Search Type Assignment.....	30
B. Search Type Definition.....	31
C. Sensor Parameter Data.....	31
D. Target Signature Data.....	33
E. Atmospheric Attenuation Data.....	33
F. Johnson Criterion Data.....	34

I. EXECUTIVE SUMMARY

A. MAJOR FEATURES OF THE TARGET ACQUISITION MODULE

The STAR Target Acquisition Module has been developed to enable the STAR (Simulation of Tactical Alternative Responses) combat simulation model to simulate various ways of using modern sensor devices for battlefield target acquisition. Major features of the target acquisition module are:

1. The model simulates a variety of electro-optical and thermal imaging systems using sensor device models developed by the U.S. Army Night Vision and Electro-Optical Laboratory, Fort Belvoir, VA (NVL).

2. Multiple observers and/or multiple sensors can be simulated for each combat entity, with provision for simulating the detailed employment of the various sensors.

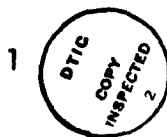
3. The model includes degradation of target acquisition due to night, weather, and smoke conditions.

4. Various levels of acquisition are modelled with provision for investigating effects on weapon employment.

B. STRUCTURE OF THE TARGET ACQUISITION MODULE

Each simulated combat vehicle (or soldier) on the STAR battlefield is assigned a user-defined "search type". The definition of a search type includes:

1. The number of observers on the vehicle.
2. For each observer, the sensor devices available to that observer.
3. For each observer, a code for the search tactic routine to be used and parameters to further define the search tactic.



By	Distribution/	Availability Codes	Avail and/or
Dist	Special		
A			

A search event for each observer is scheduled to occur periodically throughout the course of the simulation. Each occurrence of the search event for a given observer will typically perform the following functions.

1. Compile a list of potentially detectable targets for the observer using, for example, detection range limits, search sector checks, line of sight tests, and enemy/friendly checks.

2. Using the observer's search tactic, determine a sensor device to use and how it is to be used.

3. For each potential target on the list, use the NVL sensor models to determine if detection is possible. If so, compute when detection will occur and the level of target information which will be obtained. Then schedule a detection event to occur at the computed acquisition time. Details of how these functions occur are determined by the chosen search tactic and its parameters.

When a detection event occurs, if the detection is still valid (alive/dead checks, line of sight tests) the target identification and the level of acquisition attained are added to the observer's detected target list. At this point the target acquisition module has completed its work and the list is available for target selection and engagement modules which are not described in this report.

II. OVERVIEW OF THE STAR TARGET ACQUISITION MODULE

A. INTRODUCTION

This report documents a search and detection model used for target acquisition in the STAR (Simulation of Tactical Alternative Responses) ground/air combined arms combat simulation model. This target acquisition module was developed in Spring 1981 as a replacement for the original STAR detection model which used the DYN-TACS visual detection equations. Some features of the new module are the following:

1. The model simulates a variety of electro-optical and thermal imaging systems using sensor device models developed by the U.S. Army Night Vision and Electro-Optical Laboratory, Fort Belvoir, VA (NVL).

2. Multiple observers and/or multiple sensors can be simulated for each combat entity, with provision for simulating the detailed employment of the various sensors.

3. The model is designed to allow direct implementation of smoke and "dirty battlefield" degradation of target acquisition (See Reference 2).

4. Various levels of acquisition are modelled, with provision for investigating effects on weapon employment.

5. It should also be noted that the DYN-TACS visual detection model remains available as an option within the new structure.

The remainder of this Chapter gives general background on the structure of the STAR model, the structure of the new target acquisition module, and the way in which the target acquisition module uses the NVL methodology. Chapter III presents the NVL model in more detail and describes the NVL input requirements

for defining the sensor devices to be used in the simulation. Chapter IV discusses the STAR search tactics routines which define how sensor devices are to be employed by the simulated combat entities.

This report will not discuss programming details of the STAR code or of the STAR implementation of the NVL equations. Further information on these detailed aspects of the STAR Target Acquisition Module can be found in Volume II of this report - The Technical Manual (Reference 1).

B. EVENT FLOW IN STAR

The STAR combat model is an event-sequenced computer simulation written in the SIMSCRIPT II.5 language. Combat functions are simulated by a number of events or occurrences which are scheduled to occur at some future simulated time. When processing for a given event is completed, the simulation control program advances simulated time to the scheduled time of the next pending event and begins processing of the event. One important set of events relates to target acquisition and engagement. These events operate roughly as follows:

1. The SEARCH event simulates an observer searching for enemy targets. For each potential target it computes a time-to-detect, T , based on the observer/target situation. For each target whose T is short enough to assume that detection occurs, a DETECT event is scheduled to occur T seconds into the future. The search event recursively reschedules itself so that searching continues throughout the simulation.

2. When event DETECT occurs, some time, T , after the search which caused the detection, the target is considered detected (if intervisibility still exists) and is added to the observer's detected list. This may cause a TARGET.SELECT to be scheduled.

3. Event TARGET.SELECT chooses a target from the observer's detected list based on target priorities and ammunition availability. It schedules a FIRE to occur in the lay-load time for the weapon.

4. Event FIRE occurs at trigger pull time. If the weapon firing is still appropriate (e.g. if the firer is still alive) it schedules an IMPACT to occur in the projectile flight time.

5. Event IMPACT does accuracy and lethality computations for the engagement. In addition to assessing kills, it may schedule another FIRE if the target survived, a new TARGET.SELECT if the first target was killed, or other actions such as a move to a defilade position.

This is a bare-bones description of the engagement sequence in STAR, but it is sufficient to describe the requirements for a target acquisition module: The target acquisition module must simulate an observer (possibly several coordinated observers) searching for enemy targets. For each potential target the module must decide whether a detection is possible and, if so, must compute the time required for the detection to occur based on the observer/target situation and (generally) a random number draw. The target acquisition module includes the events SEARCH and DETECT along with other supporting routines.

C. BASIC STRUCTURE OF THE TARGET ACQUISITION MODULE

In the new Target Acquisition Module, the observer is the basic searching element. Each combat entity (TANK) may have as many observers as the user desires (often only one). Each observer has one or more sensor devices (unaided visual search is also considered to be a "sensor device" for ease of presentation in this report) which are used in some preplanned fashion called a search tactic.

The SEARCH event is scheduled independently for each observer on the battlefield so that the amount of time spent in one search cycle can vary according to the sensor device or the tactical situation. Within each search cycle, the search tactic defines which potential targets are considered, which sensors are used, and how they are used. The resulting detection times are computed using search and sensor models originally developed by NVL. The result of a SEARCH event is the possible scheduling of DETECT events at future times in the simulation.

The result of a DETECT event is the addition of an entry to the observer's detected list giving the identification of the detected target and a code representing the level of acquisition which has been attained. The levels of acquisition which are currently provided for are, in increasing order of information.

<u>CODE</u>		<u>LEVEL</u>	<u>MEANING</u>
1	=	Flash Stimulus	- "Something was there" - transient cueing information
2	=	Detection	- "Distinguish tank vs bush"
3	=	Classification	- "Distinguish tracked vs wheeled"
4	=	Recognition	- "Distinguish tank vs APC"
5	=	Identification	- "Distinguish M60 vs M1"

Since the original DYN TACS detection model used in STAR had only one level of acquisition - "identification", the change to the detected list structure will influence other aspects of STAR - notably target selection. This is considered beyond the scope of this report, but will be considered in the near future.

D. THE NVL DETECTION MODEL

The time-to-detect computations in the new Target Acquisition Module are performed using models developed by NVL. The NVL models were chosen for several reasons:

1. A consistent structure has been used to model a variety of optical and thermal imaging sensors.
2. There is a continuing interest at NVL in development and improvement of the models.
3. NVL is continuing efforts to validate the models against test and exercise data.
4. The models are structured in a fashion that makes it particularly straightforward to include environmental parameters such as weather, night, smoke, or dust as well as sensor parameters.

The work described in this report, especially Chapter III, was made immeasurably easier through the assistance and participation of NVL personnel, in particular Mr. Frank Shields, Mr. Marcos Sola and Mr. Carl Hoover.

The target acquisition structure is designed for maximum flexibility so that, if required, models other than the NVL time-to-detect model can easily be used. In particular, the DYNTACS/ASARS visual detection models remain available as options in STAR. Air/air defense radar models will also fit naturally into the new target acquisition structure.

III. INPUTS TO THE NVL MODEL - DEFINING SENSOR DEVICES

A. THE NVL METHODOLOGY

In this section we present a brief review of the target acquisition phenomenon and of the model which was developed by NVL to predict acquisition times. Throughout this report we will use the generic term "acquisition" to refer to any of the several levels of target acquisition as presented in Section II-C. The actual level which is being used at any point in the simulation is determined by the search tactics which are discussed in Chapter IV.

In order for a target acquisition to occur, it is necessary that the following events all occur:

1. The target must emit or reflect a target signature which is sufficiently different from the target's background to make the target noticeable.

2. The target signature must be transmitted from the location of the target to the location of the observer's sensor. For the electro-optical imaging sensors considered in the NVL model, transmission is via direct line of sight. Terrain features or vegetation may completely or partly block line of sight, possibly preventing the acquisition. Even if geometric line of sight exists, the target signature may be attenuated when it reaches the sensor location. Attenuation may be caused by weather (rain, haze, fog) or by man-made phenomena (smoke, dust).

3. The sensor must be pointing in the right direction. The sensor devices considered in the NVL model have a limited field of view (FOV) which

may be scanned across a larger field of search (FOS) or sector of responsibility for the observer.

4. Assuming that 1, 2, and 3 have occurred, an attenuated target signature is input to the sensor. This input is processed (typically electronically - exception: unaided visual search or field glasses) and the resulting image is displayed to the observer (typically on a screen).

5. Based on the characteristics of the displayed image, the observer decides (or does not decide) that a target is present. The level of detail in the displayed image determines the level of acquisition which the observer can attain.

Target acquisition is a very complex phenomenon which is influenced by numerous factors some of which are difficult to measure in the field and probably impossible to include explicitly in combat models. Thus models of target acquisition tend to be stochastic models which, given the available search time, yield a probability of detection or, conversely, given a desired probability of detection yield the time required for acquisition.

The NVL model considers each of the above aspects of the target acquisition phenomenon:

1. Target Signature. The target signature which initiates the acquisition sequence is modelled as either:

- a) Optical contrast, C , for Optical and TV viewers, or
- b) Average temperature difference, ΔT , for thermal sensors.

In each case the target signature is measured relative to the background against which the target is viewed.

In the STAR implementation of the NVL model, the target signatures are contained in a 4 - dimensional array TAR.SIG with subscripts:

SYS	-	System Type of Target
WPN	-	Weapon Type of Target
SPEC	-	Sensor Spectrum Code (Wavelength)
BKG	-	Background Type

The user is responsible for defining the SYS, WPN, SPEC and BKG values to be used in the simulation and must input the corresponding TAR.SIG values.

Five background conditions are identified by the STAR terrain/line of sight model. These are:

<u>CODE</u>	<u>DESCRIPTION</u>
1	Terrain of unspecified type (might be either ground or vegetation) beyond the near vicinity of the target
2	Sky
3	Ground in the near vicinity of the target
4	Vegetation in the near vicinity
5	Smoke cloud in the near vicinity of the target

The user may define how far behind the target the "near vicinity" is to extend for each type of sensor considered. If the user does not wish to specify target signatures to this level of detail, the model will automatically default to less detailed treatments.

2. Attenuation. Assuming that geometrical line of sight exists, attenuation of the target signature along the observer/target path is modelled as (for a thermal device),

$$\Delta T' = \Delta T \exp (-\sigma \cdot \text{range}) \quad (1)$$

where the attenuation coefficient σ depends on atmospheric conditions and on the wavelength band at which the sensor operates.

In the STAR implementation the atmospheric background condition is assumed constant over the battle time so σ values may be precomputed for each waveband. Also, an additional attenuation factor for smoke is included from the SMOKE model (Reference 2), so the attenuation equation is,

$$\Delta T' = \Delta T \exp (-\sigma * \text{RANGE} - \text{SMKATTEN}). \quad (2)$$

The attenuation coefficients are stored in the STAR 1-dimensional array ATMOS.ATTEN with subscript:

SPECTRUM = Wavelength Band Code.

The user can compute input values for this array from equations available from NVL.

Contrast attenuation for optical systems is modelled using the equation,

$$C' = C / (1 + SG * (\exp (\sigma * \text{RANGE} + \text{SMKATTEN}) - 1)) \quad (3)$$

where SG is the sky/ground brightness ratio.

3. Scanning. The process of moving a small field of view across a larger field of search is generally modelled probabilistically because it is impossible to describe deterministically where a searching observer will choose to concentrate his attention next. We postpone the NVL model of the searching process to the end of this section (under Number 6). For now assume that the sensor is stationary and pointing at the target.

4. Sensor Characteristics. The effect of the sensor on the received target signature is expressed in terms of the resolution capability of the sensor system. Since the systems being modelled are imaging systems, we are primarily concerned with the level of detail which can be displayed. Each sensor has a minimum resolvable temperature (MRT) or minimum resolvable

contrast (MRC) function which relates input signal strength to system resolving capability. In the case of a thermal system, the MRT curve can be used to convert the input target signature ($\Delta T'$) to system resolving capability measured by a maximum resolvable spatial frequency f for the detection situation being modelled. (Spatial frequency f is measured in units of cycles per milliradian.) A typical MRT curve is given in Figure 1 (Reference 5).

Then, given the exposed height h of the target (from line of sight computations) and the range R to the target, the number N of resolution cycles which can be placed on the target image is given by,

$$N = \frac{h \cdot f}{R} \quad (4)$$

where h is measured in meters, R in kilometers, and f in cycles per milliradian.

In the STAR implementation of the NVL model, the user must input a description of the MRT (MRC) curve for each device to be modelled. The curve is defined as,

$$f = \frac{C_1 + \frac{C_2 * \Delta T'}{\Delta T'}}{C_3 + \frac{C_4 * \Delta T'}{\Delta T'}} * M \quad (5)$$

where C_1 , C_2 , C_3 , C_4 are coefficients resulting from a curve fit to experimental data and where M is a magnification factor. Any given MRC/MRT curve may be composed of an arbitrary number of segments each with the above functional form. This includes the normally used NVL form ($f = Cx/A+Bx$) and also allows for piecewise linear fits.

The user must input the MRT(MRC) coefficients for each sensor and the relevant magnification factor, M , for each FOV mode. These values are available from NVL for a variety of existing and proposed sensor systems.

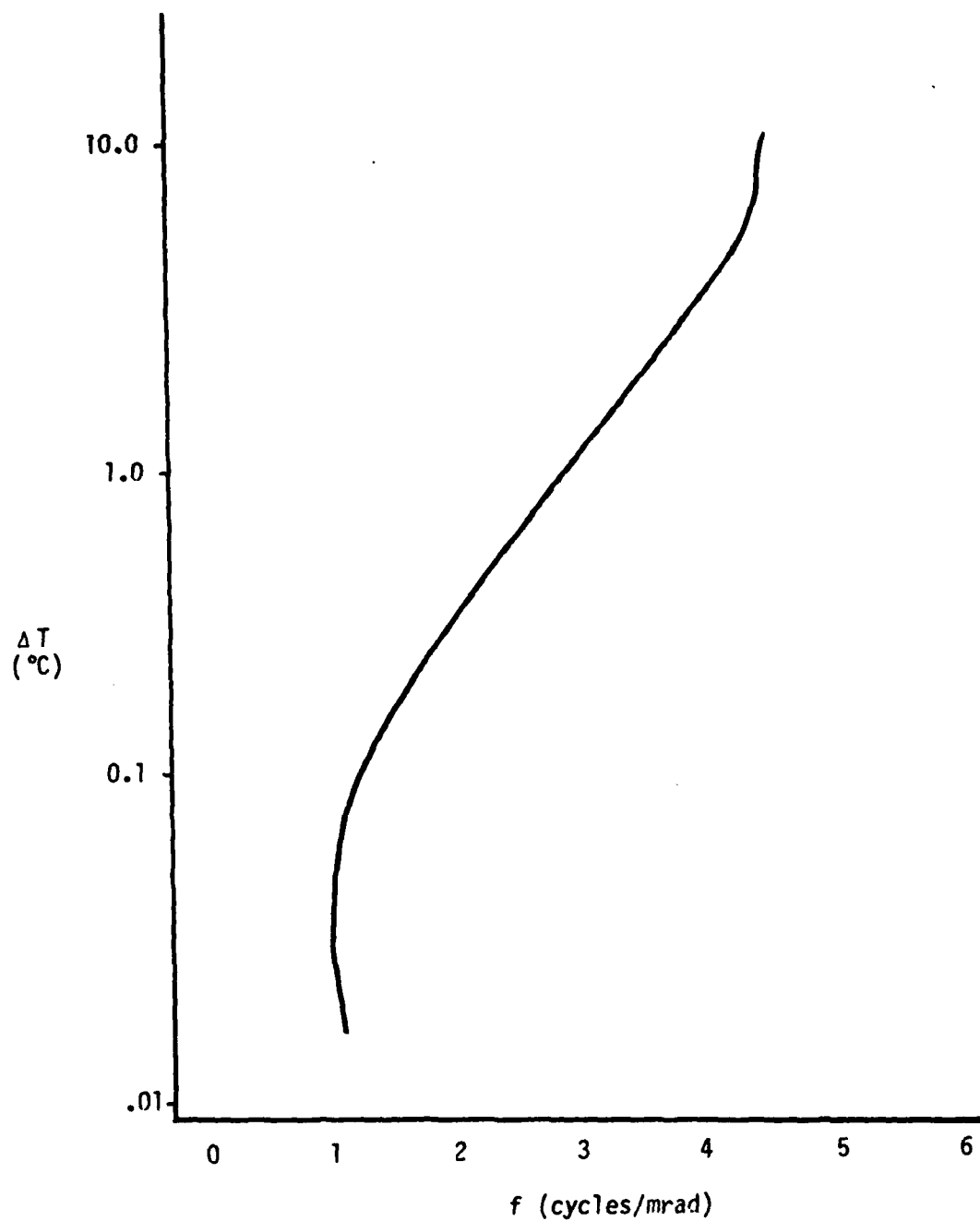


FIGURE 1 TYPICAL MRT CURVE

5. Observer Characteristics. The reaction of the observer to the displayed image which is the output of the sensor system is modelled using the methodology suggested by Johnson (Reference 3). In the Johnson procedure, levels of target acquisition such as detection, recognition, and identification are related to the number N of sensor system resolution cycles which can be superimposed on the target image (Equation 4). Detection experiments have established thresholds for the number of cycles n_{50} required to achieve 50% success in detecting (recognizing, identifying) military targets. Typical values of n_{50} are given in Figure 2 (Reference 5). A target transform probability function (TTPF) has been developed from these experiments which relates the probability of target acquisition to the value of N . The TTPF function follows a normal distribution with mean = n_{50} and standard deviation about $0.6 \times n_{50}$. The resulting probability of target acquisition is called P since it assumes essentially infinite time available for the acquisition - up to this point we have ignored searching.

In the STAR implementation of this phase of the NVL model the n_{50} values are stored in a 3-dimensional array N50TABLE with subscripts,

- SEN - Sensor Device Code,
- ACQ - Acquisition Level Code,
- K - K = 1 Stationary Target, K = 2 for Moving Target

The user must input these values. The TTPF function is defined in the code and cannot be changed by user inputs.

DISCRIMINATION
LEVEL

CYCLES FOR 50%
PROBABILITY

Detection

1.0
(0.5 for moving
targets)

Classification

2.0

Recognition

3.0 optical systems

4.0 thermal systems

Identification

6.4

FIGURE 2 TYPICAL n_{50} VALUES

6. Search. The P_{∞} detection probability value must be decreased to account for the fact that in typical target acquisition situations, the observer can not spend an infinite amount of time looking at a single point. Rather, the observer must repeatedly search his entire sector of responsibility using a device having a relatively small field of view. In addition, as the sensor device FOV is moved across the total search area, the observer must visually search the display screen of the sensor device. A model for this rather complicated search process has been presented by Lawson (Reference 4). Only the results of Lawson's derivation are presented here.

Let t_o = the time required for the observer to search one device FOV. Field tests have shown that t_o is essentially constant and the model uses $t_o = 1.7$ sec.

Let P_s = probability of detecting the target in a search of one device FOV conditional on the target being in the FOV and conditional on eventual detection. The standard exponential search model gives,

$$P_s = 1 - \exp(-t_o/\tau) \quad (6)$$

where τ has been found from field experiments to be well approximated by,

$$\tau = \frac{6.4 \times n50}{N} \quad (7)$$

and thus

$$P_s = 1 - \exp\left(-\frac{1.7}{6.4} \times \frac{N}{n50}\right) \quad (8)$$

Let t_s = time required to systematically scan the entire field of search. If the field of search has vertical size greater than the device vertical field of view ($VFOS > VFOV$) then a 2-dimensional scan is used with,

$$t_s = \frac{\text{search area}}{\text{FOV Area}} \times t_o = \frac{\text{HFOS} \times \text{VFOS}}{\text{HFOS} \times \text{VFOV}} \times t_o \quad (9)$$

Otherwise let

$$t_s = \frac{\text{HFOS}}{\text{HFOV}} \times t_o \quad (10)$$

for a 1-dimensional scan.

Here HFOS, HFOV, VFOS, VFOV are the angles covered by the horizontal and vertical measurements of the field of search and field of view.

Assuming complete systematic scans of the field of search (FOS) define τ_1 = mean acquisition time given that the target is found. Lawson (Reference 4) gives the relationship,

$$\tau_1 = t_s (2 - P_s) / 2 P_s \quad (11)$$

Finally, the probability of detection in time t is given as,

$$P(t) = P_\infty (1 - \exp(-t/\tau_1)) \quad (12)$$

again using the standard exponential model. For STAR simulation purposes, this equation is used to compute a stochastic time to detect as follows. Let $U \sim \text{Uniform}(0,1)$ be a uniform random number. If $U \geq P_\infty$ then no detection can occur. If $U < P_\infty$ then solve (12) above for t giving,

$$t = -\tau_1 \ln(1 - \frac{U}{P_\infty}) \quad (13)$$

The STAR implementation requires that HFOV and VFOV be input for each sensor device. HFOS and VFOS are observer values which are assumed to be supplied by the battle plan.

B. EXTENSIONS

Since the original Johnson n50 values were developed for static detection of single targets in uncluttered areas, modifications are in order for moving targets, moving observers and cluttered backgrounds. The model has been found

to produce reasonable values when compared with field experiments and NVL is continuing with further research in this area. The STAR implementation has a separate plane of the N50TABLE array for stationary vs. moving targets.

The input values which the STAR target acquisition model requires for sensor definition will be repeated in Chapter V in the order in which they are read by the STAR computer program.

IV. INPUTS TO SEARCH TACTICS - USING SENSOR DEVICES

A. THE CONCEPT OF A SEARCH TACTIC

The incorporation of the NVL search model into the STAR combat simulation makes it possible to simulate a wide variety of target acquisition devices and situations. This capability to simulate multiple observers, multiple sensors, various modes of sensor use and various levels of target acquisition creates an obligation for the model builder and user to cooperate in defining realistic modes of employment for the sensors that are made available to each observer. These modes of sensor employment will be called search tactics.

The search tactic for a given observer will typically include the following sorts of computations:

1. Preliminary Target List Management. If the observer has moved into a full defilade position, his entire target list might be erased or the acquisition level might be lowered for targets on the list, thus requiring some effort for reacquisition when he emerges from defilade. Transient target signatures such as gun flashes which have not been upgraded to higher acquisition levels during the previous search event might be removed from the list.

2. Determine Area to Search. Each entity in the simulation has a primary direction of search related to its sector of responsibility. The search tactic must decide whether to search the entire sector during this search cycle, or whether to concentrate on some smaller subarea possibly around a direction in which searches have recently been successful. Alternatively the tactic may decide not to search, but rather to "stare" at already localized targets in an attempt to upgrade their acquisition levels.

3. Create a Set of Potential Targets. Usually, only a small subset of the elements on the battlefield are in a position to be detected by a particular observer. Simple tests may be used to screen out obviously ineligible targets. Examples include enemy/friendly tests, range checks, sector checks, and line of sight tests. Targets which pass the screening tests can be filed in the potential target set in order of (for example) range so that closer targets will be considered first in the detection computations. Also, some systems, such as air defense, are only interested in particular enemy elements (e.g. air) so only those would be filed in the set.

4. Specify Sensor Device Utilization. The search tactic must select the sensor device to be used (if the observer has more than one device available). It must choose between wide and narrow field of view and it must decide whether to scan across the field of search or to stare at specified points in the field of search. Some search tactics may involve switching between wide and narrow FOV or even switching from one sensor to another. In such a case the tactic must include decision logic to trigger the change. The tactic must also specify the acquisition level which the observer is trying to attain.

5. Compute Time to Detect. Once the sensor device mode of use is specified, the NVL detection time model can be used to compute a time-to-detect for all or some subset of the targets in the potential target set. Times for switching devices or switching from wide to narrow FOV should also be included as appropriate. The search tactic must determine whether the acquisition times so computed for several targets are to be considered as having occurred simultaneously (as might be appropriate in a wide FOV search of a target-rich area)

or sequentially (if a narrow FOV device is being used to stare at previously localized targets one at a time).

6. Schedule Detection Events. For targets whose acquisition time is small enough, a DETECT event must be scheduled by the search tactics routine. The search tactic must specify the time threshold and perhaps a limit on how many targets can be acquired in one search cycle.

7. Schedule a New Search. Finally, the search tactic must decide when to terminate the current search event and thus the time at which the next SEARCH event for this observer should be scheduled to occur. Termination of the current search may occur because of an elapsed time threshold, or because of a limit on the number of targets acquired, or some combination of the two thresholds.

The variety of different computations which may be called for in a search event, and the options of multiple sensors and modes of employment make it unlikely that any single search tactic will be appropriate for all situations that we would like to simulate. Thus the approach to search tactics taken in STAR is to have several possible search tactics each represented by its own routine. Each tactic has parameters (such as the sensor device to be used) which customize it to a particular observer. New search tactics may be added by writing an appropriate new tactics routine without having to adjust the code for existing tactics.

B. ASSOCIATING A SEARCH TACTIC AND SENSORS WITH AN OBSERVER

Each combat entity in the STAR simulation has a single search type attribute (called SCH.TYPE) which is used to determine how it will search for targets. SCH.TYPE is an integer data input value which must be supplied for

each entity by the user. There is no limit on the number of different search types which can be used. At one extreme, all of the entities in a simulated battle might use the same search type. In this case, they would all be equipped with the same sensor device(s) and would use their sensors in the same way (i.e. would use the same search tactic). At the other extreme, a unique search type might be defined for each entity on the battlefield. A more likely middle ground would associate a different search type with each system type/weapon type combination.

Each search type that is used must be defined by the STAR model user. The definition of each search type is kept in a data array SCH.DATA and includes the following:

1. TYPE - integer code number for this search type.
2. NOBS - integer number of observers for this combat system.
3. For each of the NOBS Observers:

(a) TAC - integer code for the search tactic to be used by this observer.

(b) NPARS - integer number of parameters for this tactic.

(c) PAR2, PAR3... - real valued parameters which customize the search tactic to this observer (NPARS parameters are read with the tactic number considered to be the first parameter). Examples of how the parameters are used to customize the search tactic will be given in the next section where a specific search tactics routine will be discussed.

During execution of the STAR model, SEARCH events occur periodically. Each SEARCH event is identified by three parameters, SEARCH (A, OBS, TYPE), where A is the pointer to the SIMSCRIPT combat entity, OBS is the number of the

observer on that entity whose search event is occurring, and TYPE is the SCH.TYPE for that observer. The SCH.DATA array is then accessed using the specified search type and observer as index values to determine the search tactic to be used and the parameters for that tactic. The SEARCH event then calls the appropriate search tactic routine to do the target acquisition computations. The tactic routine attempts to schedule DETECT events and keeps track of the amount of battle time spent doing the searching. It returns the total elapsed time when it finishes its computations. The SEARCH event then reschedules itself to occur again (for this observer) after that amount of battle time has passed.

C. PARAMETERS FOR A SINGLE - SENSOR SEARCH TACTIC

In this section we discuss a simple single-sensor search tactic called STK2 from the STAR code. The SCH.DATA array for an observer using tactic STK2 must specify the following parameters.

TAC	- The Tactic Number - in this case 2.
SENSOR	- Sensor to be used.
MODE	- Mode of use for the sensor (wide or narrow FOV).
LO.ACQ.LEV	- Lowest acquisition level to consider.
HI.ACQ.LEV	- Highest acquisition level to consider.
HFOS	- Horizontal field of search.
VFOS	- Vertical field of search.
MAXN	- Maximum number of targets to acquire in one search cycle.
MAXTIME	- Maximum time to spend in one search cycle.
MINTIME	- Minimum time to spend in one search cycle.

SIMUL	- Simultaneous (Code = 1) or sequential (Code = 2) search time.
FOVSW	- Time for switching FOV to narrow mode after localizing target (used only in sequential mode).
MAXEACH	- Maxtime to spend on any one target (should equal MAXTIME for simultaneous search).
SOURCE	- 1 = potential targets from scan of the battlefield 2 = potential targets from own detected list.
PURGE	- Purge level for detected list.
NEWTYP	- SCH.TYPE to use for next search by this observer.

In the remainder of this section we will discuss the computations that are performed in each call to the search tactics routine STK2 in terms of these parameters. We shall follow the outline used in Section IV-A.

1. Preliminary. If the observer is dead, the SEARCH event terminates immediately without calling STK2 and without scheduling a future SEARCH. Otherwise routine STK2 is called to do the target acquisition computations. If the observer is totally suppressed, then no detections are attempted, this SEARCH cycle ends, and the next SEARCH event is scheduled MAXTIME seconds into the future. Otherwise, if the observer is in full defilade then his detected target list is released, no detections are attempted, this SEARCH cycle ends, and the next SEARCH event is scheduled in MAXTIME seconds. If the observer, passes these preliminary tests, then detection computations will occur during this SEARCH event.

2. Determine Area to Search. If the observer's detected target list is empty (indicating recent unsuccessful searching) then he will change his primary search direction. Otherwise he will continue to search in the same direction as previously used.

3. Create a Set of Potential Targets. If SOURCE = 1, all enemy entities are screened to determine if they are potential targets. Those which are within the observer's maximum acquisition range and which are inside the observer's current search sector are filed in the set of potential targets ranked by range, so that the closest will be considered first. If SOURCE = 2, then potential targets are taken from the searcher's own detected list and filed as above in the potential target set.

4. Specify Sensor Device Utilization. The sensor and its mode of utilization are determined by the STK2 parameters SENSOR, MODE, LO.ACQ.LEV, HI.ACQ.LEV, HFOS, and VFOS.

5. Compute Times to Detect. Targets in the potential target set are considered one at a time in order. (If the set is empty, then the SEARCH event uses MAXTIME seconds and fails to acquire any targets.) For each potential target the following computations are performed. First the observer's detected target list is checked to see if the potential target is already on the list with an acquisition level at least as high as HI.ACQ.LEV. If so, this target is not considered further. Otherwise the NVL routine is called to compute a time-to-acquire and an acquisition level attained for this potential target. Any suppression time for detection is added to the NVL time to give a total acquisition time, T, for this target.

6. Schedule Detection Events. The use of this acquisition time T depends on whether the SIMUL parameter indicates simultaneous or sequential searching. First consider the simultaneous case. If T is less than MAXTIME, then a DETECT event is scheduled in T seconds after the start of this SEARCH event. If T is

greater than MAXTIME, then this target is not acquired during this search cycle and the time used by this search cycle is set to MAXTIME. Whether or not this target is acquired, the computations are continued for other targets in the potential target set since we are assuming that several can be detected simultaneously.

In the sequential case, computations begin with an available time of MAXTIME. As T is computed for each potential target, it is compared with the remaining available time. If T is less than the remaining time, then a DETECT event is scheduled in T seconds after the previous detection, the remaining time is decreased by T , and computations continue to the next potential target. If T is greater than the remaining available time, then the search cycle ends without acquiring this target and the time used by this cycle is MAXTIME. Once the remaining time is exceeded, no further potential targets are considered. In any case, at most MAXEACH time will be used for each target.

In both the simultaneous and sequential cases, if MAXN targets have already been acquired during this search cycle, then no further potential targets are considered.

7. Purge the Detected List. At the end of the potential target set processing, if $PURGE > 0$, then any target on the detected list with acquisition level less than $PURGE$ is removed from the list.

8. Schedule a New Search. Finally, a new SEARCH event must be scheduled for this observer. Usually this event will be scheduled MAXTIME seconds after the current SEARCH event. However, if MAXN targets are acquired without a failure before MAXTIME seconds have elapsed, then the computed acquisition times (largest if simultaneous, total if sequential) will determine the time

used by this search cycle and thus the time interval for scheduling the next SEARCH. In no case will the time used be less than MINTIME. The new SEARCH event will specify that search type NEWTYPE is to be used for the next search cycle.

D. APPLICATION OF THE STK2 SEARCH TACTIC

In this section we will briefly show how the STK2 search tactic routine may be customized (through setting its 16 parameters) to represent a particular target acquisition behavior. Consider the situation of an observer scanning his search sector using unaided visual search and hunting for any indication of possible military targets. When targets are detected, the observer will switch to field glasses, focussing on each target in turn in an attempt to obtain as high a level of acquisition information as possible. Then the observer will revert to unaided visual search as before.

This pattern of target acquisition behavior can be modelled in the STAR Target Acquisition structure by using two search types. Search Type 1 will specify the details of the unaided visual search, and will be the search type stored on the observer entity. Search Type 2 will specify the details of the attempt to upgrade the acquisition level of detected targets using field glasses. It will be invoked using the NEWTYPE argument at the end of search Type 1. Both search types will specify the use of search tactic STK2.

Search Type 1 has the following list of STK2 parameters (some of them chosen rather arbitrarily for this simple example):

TAC	- Use search tactic STK2
SENSOR	- Unaided visual

LO.ACQ.LEV	- Detect	in this part of the search we only want to quickly attain a low level of target information.
HI.ACQ.LEV	- Detect	
HFOS	- 90°	cover the observer's entire search sector
VFOS	- 15°	
MAXN	- 5	detect up to five targets before switching to field glasses
SIMUL	- Simultaneous search times	
SOURCE	- Potential targets from battlefield scan	
MAXTIME	- 30 Sec	
MINTIME	- 15 Sec	
MAXEACH	- 30 Sec	
NEWTPE	- 2	use field glasses for the next search cycle for this observer

Search Type 2 has a different set of parameters, so even though it uses the same STK2 tactics routine, it represents different search behavior. The Type 2 parameters are:

TAC	- Use search tactic STK2	
SENSOR	- Field Glasses - NVL simple optics	
LO.ACQ.LEV	- Detect	Cover the entire range of NVL acquisition Levels
HI.ACQ.LEV	- Identify	
HFOS	- 3°	set to a single FOV to simulate registering field glasses on a previously localized target.
VFOS	- 3°	
MAXN	7	examine up to 7 targets before reverting to unaided search

SIMUL	- Sequential Search Time
SOURCE	- Get potential targets from the observer's own detected list (they get onto that list during the unaided visual search cycle).
MAXTIME	- 40 Sec
MINTIME	- 15 Sec
MAXEACH	- 10 Sec
	After 10 seconds, if the observer can't get more information on a given target he will move on to another
FOVSW	- 3 Sec
	Time to register on a new target and change FOV
NEWTYP	- 1 Sec
	Use unaided visual search for the next search cycle for this observer

This simple example illustrates some of the possibilities of customizing a search tactic routine to represent individual target acquisition behavior. It is anticipated that STK2 will be useful in many target acquisition situations, but that the need will also arise to develop new search tactics routines. The Target Acquisition Module has been designed to make it easy to interface new tactics into STAR without having to change any existing tactics routines.

V. SUMMARY OF TARGET ACQUISITION INPUT PARAMETERS

The data input to the Target Acquisition Module is concentrated in routine RES.SCH. In this Chapter we list, in order, the input values which are read by the RES.SCH routine. SIMSCRIPT code for the RES.SCH routine and details of the data structures used are given in Volume II of this report (Reference 1). The data inputs to the Battlefield Smoke Module, which also impact on target acquisition, are read in routine SMK.RES which is documented in Reference 2.

The input data for RES.SCH is divided into several major segments.

- (a) Search Type Assignment
- (b) Search Type Definition
- (c) Sensor Parameter Data
- (d) Target Signature Data
- (e) Atmospheric Attenuation Data
- (f) Johnson Criterion Data

Each of these segments will be discussed in turn. All input is SIMSCRIPT free format input with at least one blank space between adjacent data values.

A. SEARCH TYPE ASSIGNMENT

Each system type/weapon type combination in the simulation is assigned a search type. There are NUMBER.OF.SYSTEMS such combinations (a global variable read earlier). For I = 1 to NUMBER.OF.SYSTEMS input three values:

SYS	INTEGER	System Type of Searcher
WPN	INTEGER	Weapon Type of Searcher
SCH	INTEGER	Search Type to use for this Sys/Wpn Type

(Note that SIMSCRIPT will cheerfully read an integer data value into a real variable, but an attempt to read a number with a decimal point into an integer variable will cause the program to immediately terminate (even if the number has an integer value such as 3.0))

B. SEARCH TYPE DEFINITION

This input section declares search type numbers and assigns search tactics and their parameters to each search type.

INPUT:

MXTP INTEGER Largest search type code to be used

NTYPS INTEGER Number of search types to be defined

For I = 1 to NTYPS input the definition of a search type as:

TYPE INTEGER The type code number

NOBS INTEGER The number of observers on any vehicle using
this search type

For J = 1 to NOBS input the search behavior for one observer as:

TAC INTEGER search tactic to use

NPARS INTEGER Number of parameters for this search tactic

For K = 2 to NPARS input the parameters:

PARAMETER REAL (Note that TAC is stored as the first
parameter and it has already been read)

C. SENSOR PARAMETER DATA

This input segment defines the parameters for the NVL sensor devices:

INPUT:

NSENS INTEGER Number of sensors to define

If NSENS = 0 then routine RES.SCH terminates with the assumption that the NVL detection model will not be used. Otherwise input continues:

INPUT:

MXSEN INTEGER Largest sensor code number to be used

For I = 1 to NSENS input data for one sensor as:

SEN INTEGER Sensor code number

MXMODE INTEGER Largest sensor mode code for this sensor

NMODES INTEGER Number of modes for this sensor

For J = 1 to NMODES input data for one mode as:

MODE INTEGER Mode code

MAXRG REAL Maximum sensor detection range

THR REAL Minimum sensor input threshold

SPECTRUM INTEGER Wavelength band code

HFOV REAL Horizontal field of view

VFOV REAL Vertical field of view

MAG REAL Magnification factor

GAIN REAL Optical gain (e.g. simple optics has 30%
loss so gain is 0.70)

BKGRG REAL Range beyond target to consider in
background computations

DEV INTEGER NVL device code number

After all NSENS sensors are defined, the NVL device MRC/MRT curves are entered. The format and values for the coefficients which define these curves vary considerably by the specific devices being simulated. The details of this input section are too complex to be of interest to an ordinary user and will not be included in this report.

It should be noted that several sensors may use the same MRC/MRT curve by assigning their DEV sensor parameter to be the same. Thus, for example,

numerous different optical viewers can all share NVL device code = 2, but may have different FOV's, magnifications, and system gains.

D. TARGET SIGNATURE DATA

Target signatures are input as a function of system/weapon type, spectrum, and background code:

INPUT:

NSPEC	INTEGER	Number of spectral bands
MXBKGND	INTEGER	Number of background codes to use

For I = 1 to NUMBER.OF.SYSTEMS input data for this target system as:

SYS	INTEGER	System type of target
WPN	INTEGER	Weapon type of target

For J = 1 to NSPEC input data for one spectral band for this target as:

SPECTRUM	INTEGER	Spectral band code
----------	---------	--------------------

For K = 1 to MXBKGND input:

SIG	REAL	The target signature for this combination of SYS/WPN/SPECTRUM/BKG
-----	------	---

E. ATMOSPHERIC ATTENUATION DATA

A single background atmospheric condition is assumed to hold over the entire battlefield and over the duration of the simulation.

INPUT:

SKY.GROUND	REAL	Sky/ground brightness ratio
NSPEC	INTEGER	Number of spectral bands

For I = 1 to NSPEC input:

ATTEN	REAL	Attenuation coefficient for spectral band I
-------	------	---

F. JOHNSON CRITERION DATA

Johnson Criterion Data is input as function of sensor device, acquisition level, and target movement.

INPUT:

MXDEV INTEGER Maximum device code

NDEVS INTEGER Number of device codes

For I = 1 to NDEVS input data for one sensor device as:

IDEV INTEGER Device code

For J = 1 to 5 input:

N50S REAL Johnson criterion for stationary target
 at acquisition Level J for this sensor

For J = 1 to 5 input:

N50M REAL Johnson criterion for moving target at
 acquisition level J for this sensor

REFERENCES

1. Hartman, J. K., "A Target Acquisition Module for the STAR Combined Arms Combat Simulation, Volume II - Technical Manual", Naval Postgraduate School, Technical Report NPS55-82-002.
2. Carpenter, H. J. and J. K. Hartman, "The STAR Battlefield Smoke Module", (Forthcoming).
3. Johnson, J. "Analysis of Image Forming Systems", Proceedings of Image Intensifier Symposium, October 6 - 7, 1958, pp. 249-273.
4. Lawson, W., T. Cassedy, and J. Ratches, "A Search Model", Proceedings of the IRIS Specialty Group on Imaging, June 1978.
5. Shields, F and W. Lawson, "E-O System Evaluation at NVEOL", Nightvision and Electro-Optics Laboratory, Visionics Division, January 1980.

DISTRIBUTION LIST

	NO. OF COPIES
Library, Code 0142 Naval Postgraduate School Monterey, CA 93940	4
Dean of Research Code 012 Naval Postgraduate School Monterey, CA 93940	1
Library, Code 55 Naval Postgraduate School Monterey, CA 93940	1
Professor James K. Hartman Code 55Hh Naval Postgraduate School Monterey, CA 93940	130
Defense Technical Information Center ATTN: DTIC-DDR Cameron Station Alexandria, Virginia 22314	2

MED
-8